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Controlling Bulk Material Packing Density in COUPi DEM Model to Simulate Lunar Regolith: POSTER

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Introduction

- Packing density or void ratio is one of the most important parameters that significantly affects regolith response.
- Preparing numerical material in DEM with particular packing density is a non-trivial task.
- Question: **How consistently can the required bulk properties for the material be represented in DEM?**

COUPi DEM

- COUPi is a discrete element method model developed as part of a NASA Lunar Science Institute project
- It can model interactions between particles of different shapes including polyhedral particles and machine parts
- The model has a computational “core” and “scenario” scripts allowing it to be used to build new tests and extend the model
- COUPi Creator is a program for creation of new particles
- COUPi Display is a visualization tool

Particles in COUPi

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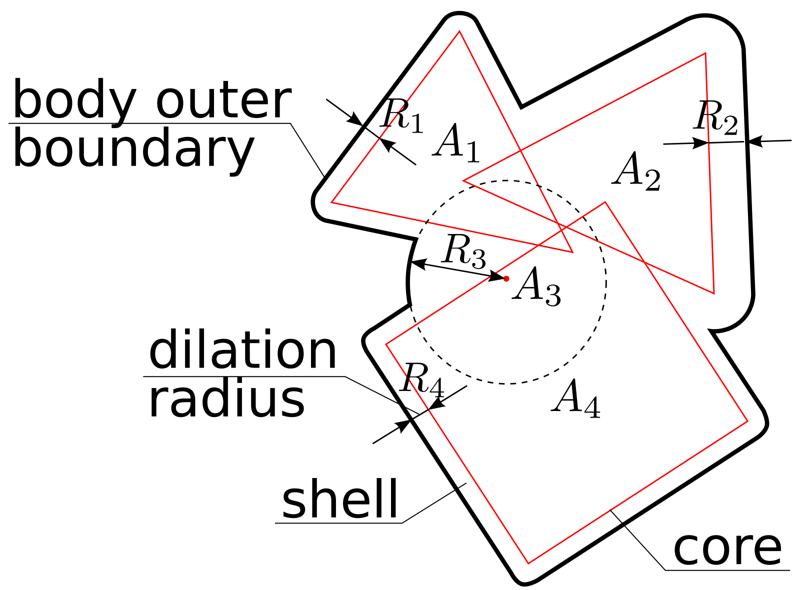
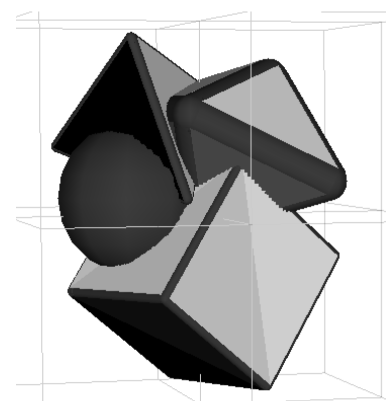
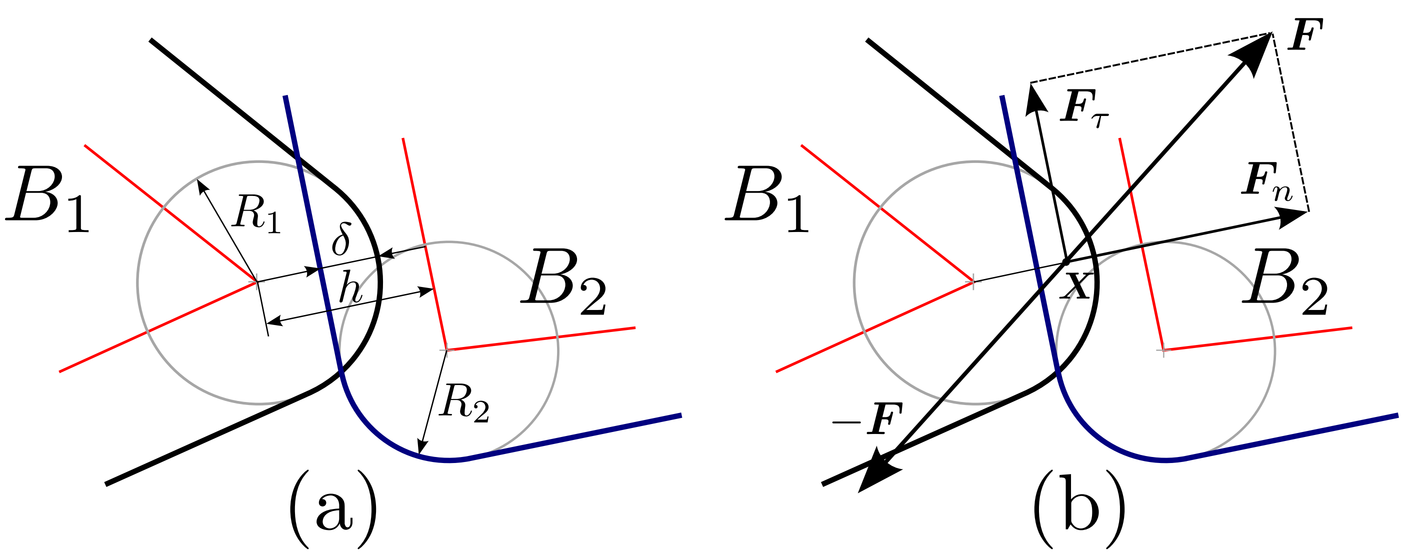
- Particles in COUPi are represented as a union of convex dilated polyhedra sub-shapes. A particle body in the following example is represented as a union of 4 atoms A1, A2, A3, and A4 with different dilation radii R1, R2, R3, and R4. The cores of atoms are the actual frames of polyhedra sub-shapes (red). The core of Atom A3 is an isolated vertex which makes the atom a sphere of radius R3. A *shell* is a part of the atom that is formed by a dilation radius. The outer boundary of all shells form an outer boundary of the body.





Interaction Forces

- Interaction of two bodies. The forces are defined by contact properties, an overlap between the bodies, and the history of the contact



Materials and Contact Properties

- Every element in the COUPi DEM model has defined material properties
- Contact properties are defined by a contact properties table that sets properties to each pair of materials
- Contact properties can be updated "on the fly" during computations
- Basic idea: **temporarily varying (artificially) the contact properties is a possible way to adjust bulk properties**

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Procedure Description

- Create a DEM particle bed by a gravitational deposition.
- Create the particle bed by portions creating layers of material with necessary bulk properties
- Each layer is set in 3 stages:
  - Stage 1: Contact friction is set to extremely high values. Particles are generated in a mesh and fall under gravity forces until settled
  - Stage 2: Contact friction is set to artificially low values depending on the packing density required, particle shapes, and particle size distribution until the layer is resettled
  - Stage 3: Contact friction is restored to physical value. The layer is settled to the required bulk density.

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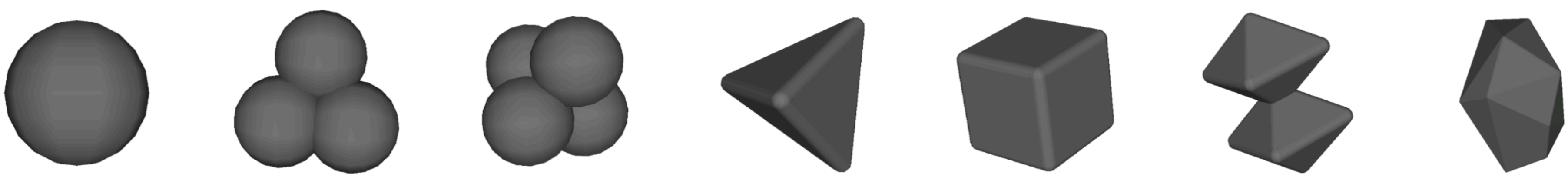
Particle Shapes

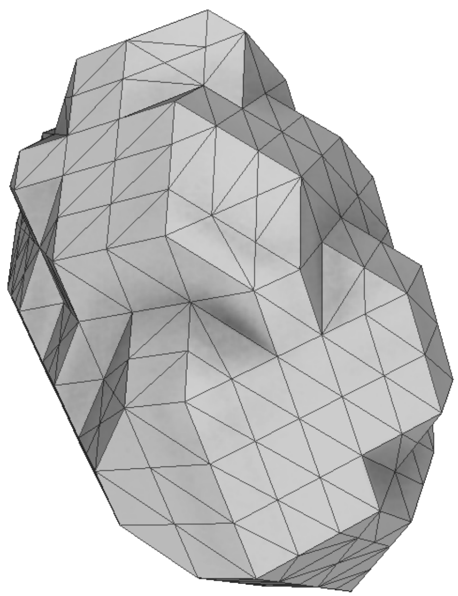
- Particles shapes used in simulations



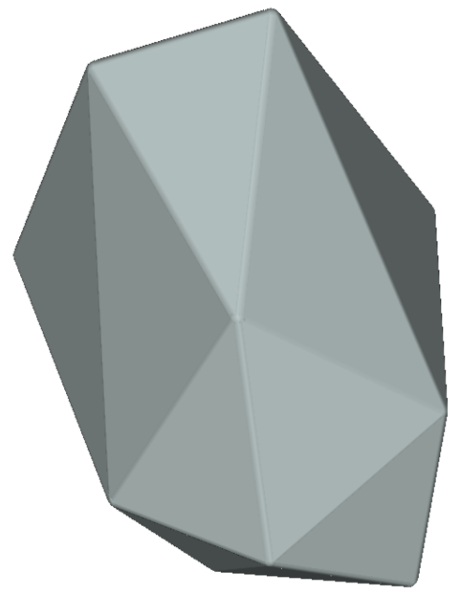
(a) Sphere (b) 3-sphere (c) 4-sphere (d) Tetra (e) Cube (f) 2-octa (g) GRC

Realistic Particles

- Simplified models of CT-scans of lunar simulant (GRC-3 or JSC-1A) are recreated using COUPi Creator

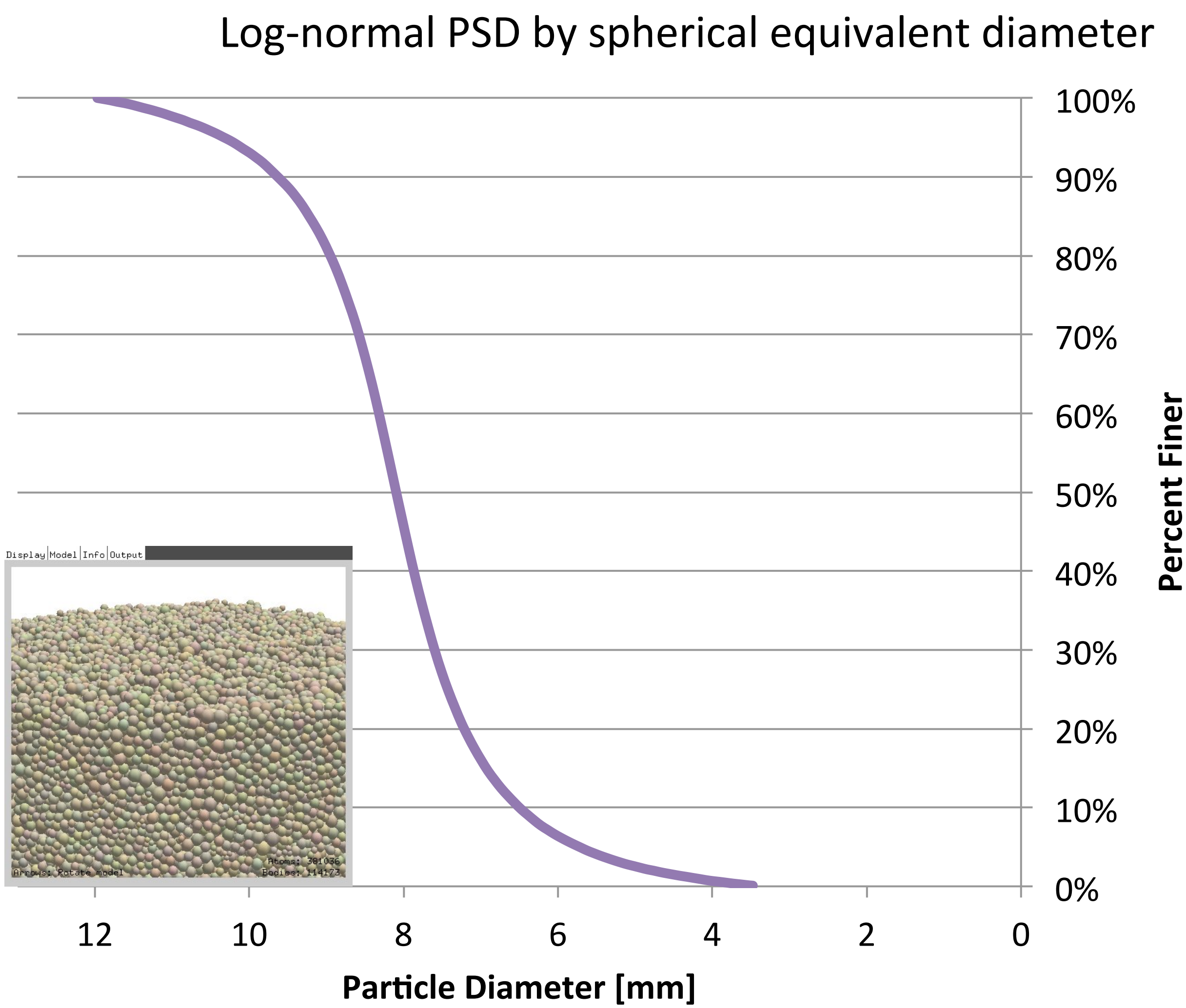


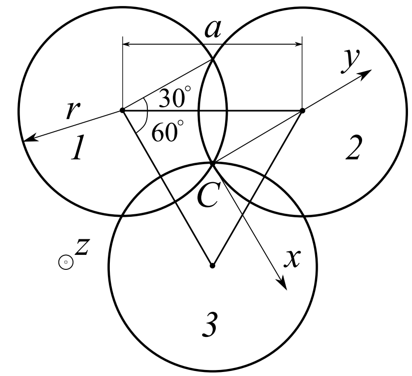
Digital triangulated mesh of CT-scan of GRC-3 particle



Simplified polyhedral model of the particle

Particle Size Distribution





Filling the Barrel and Compaction

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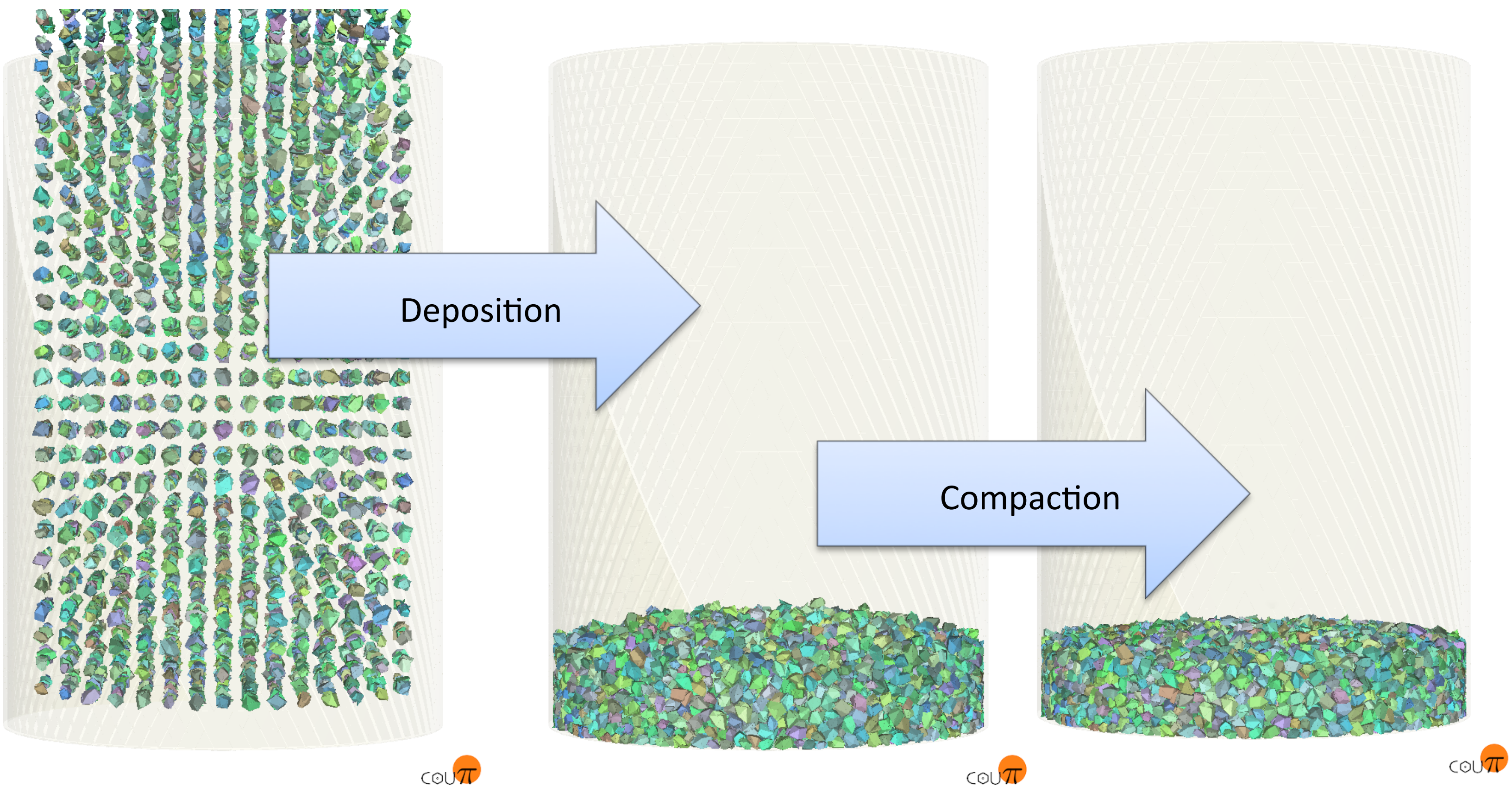
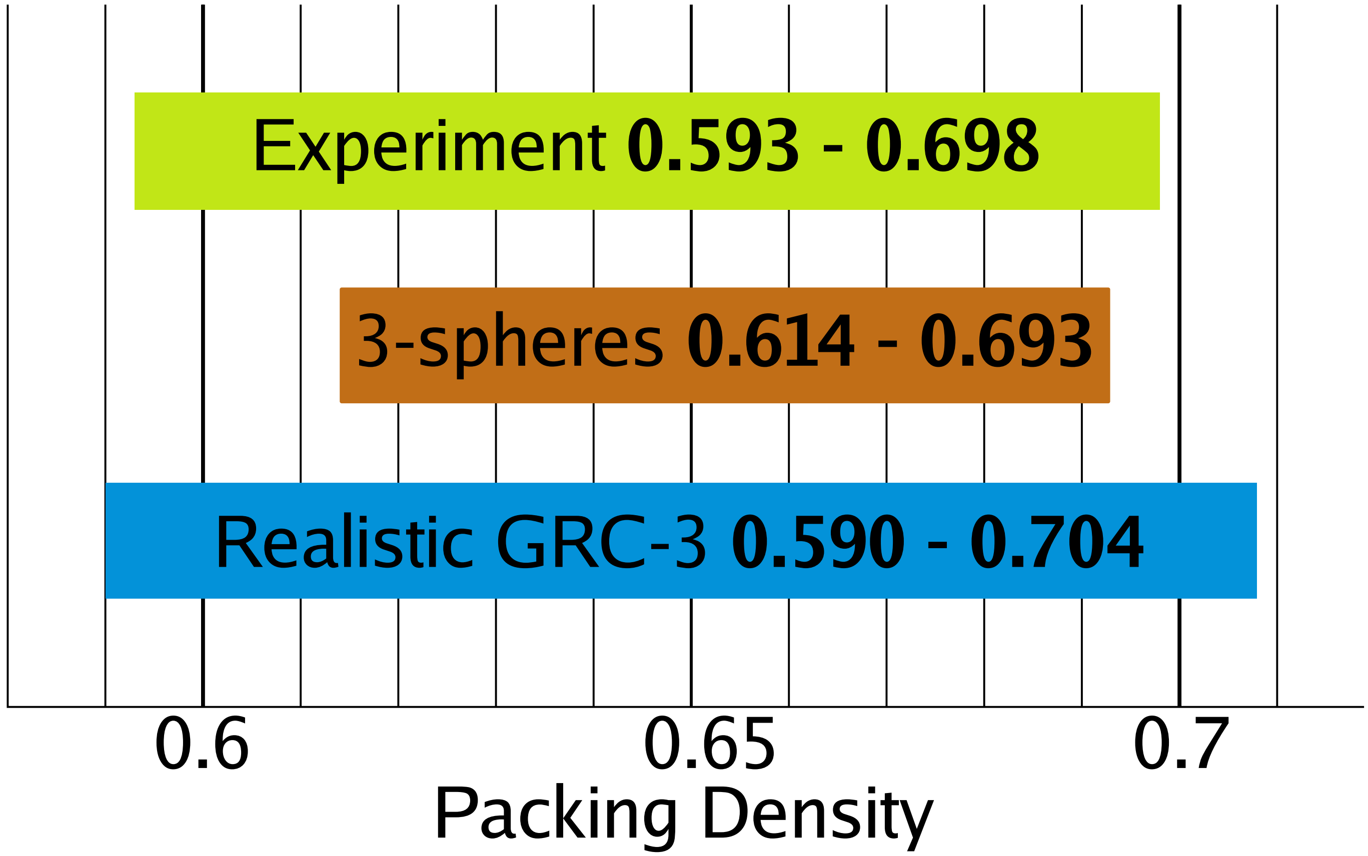


Packing Density Range Comparison



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Conclusions

- Bulk properties such as the packing density of material in DEM model can be controlled by a special procedure of material preparation developed in this work
- The key property of the model is an ability to vary contact properties and temporarily set up artificial friction between particles to either make the sliding difficult or allow easy sliding of elements
- Particles made from spheres allow more limited packing density range compare to polyhedral particles
- We are able to achieve the whole packing density range achieved in experiments using our developed procedure and polyhedral particles representing CT-scans of actual lunar simulant